Determination of Stress Fields with high local Resolution

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Using the MAXIM-setup at beamline G3 [1] residual stress in friction stir and laser welds in magnesium and aluminium samples was determined with the \((\sin^2\Psi)\)-method [2].

The new techniques of friction stir and laser welding allow the joining of light-weight materials like aluminium and magnesium alloys which were difficult to weld with conventional arc welding techniques. This allows new possibilities for the production in automotive and aerospace industries. The characterisation of these welds requires microstructural analysis and residual stress determination. Therefore X-ray diffraction is used as a non destructive technique. One Bragg-peak is measured under different incident beam angles, where \(\Psi\) is the angle between surface normal of the sample and the scattering vector. The stress is calculated from the peak shift as function of \((\sin^2\Psi)\). The MAXIM-setup at beamline G3 allows the simultaneous investigation of larger sample areas (up to 12 x 4 mm\(^2\)). Due to the used wavelength of about 1.78 Å surface near residual stress could be detected. The penetration depth is in the order of 10 to 20 µm. The result of measurements with this setup is a position sensitive determination of the stress in the surface near region. The spatial resolution at beamline G3 is about 13 µm.

A marking of the sample with a substance without diffraction peak in the scan region is necessary. With this marker corresponding sample positions in scans with different incident beam angles could be found. The calculation of the residual stress is done pixel wise. It requires diffraction peaks in all pixels for all scans. Due to the crystallinity especially of magnesium samples this condition is usually not fulfilled. This means that data for some pixel are missing. Therefore the pixel size was enlarged by using a binning. Another possibility is the use of a median or smoothing algorithm on the stress values of neighbouring pixel. This procedure also eliminates unrealistic high or low values.

The result of such an examination of laser welded magnesium is shown in figure 1. The data were processed using a binning of 10 x 10 pixel, resulting in a spatial resolution of 130 µm. For smoothing the mean of a 3 x 3 array of this super pixel was calculated and stored in the centre pixel. Also a median filter was used in the same 3 x 3 pixel arrays. This filter ignores the highs and the lowest values and stored the mean of the other seven pixel in the centre pixel. The weld itself is orientated horizontally in the middle of the map (between 4.5 and 5.0 mm) with a stress of -70 MPa (mean value) and an error of 120 MPa. The result for the basic material is a stress of -75 MPa (mean value) with a mean error of 75 MPa. The residual stress of basic material and weld are comparable but the error of the values of the weld is noticeable higher. Also areas of very low residual stress and higher error are on both sides of the weld in a distance of 2.5 mm visible. The origin of these areas is still under examination.

Competitively measurements with a scintillation counter were performed. These measurements were done with a beam of 1 x 1 mm\(^2\) so an integral value over a relatively large area is measured. For the basic material at four different positions measurements with the scintillation counter were done. The evaluations are under way.
Figure 1: Stress distribution (left) and error (right) of a weld in laser welded magnesium. The weld is horizontally orientated in the middle of the map (between 4.5 and 5.0 mm on the vertical axis). The marker is visible in the lower right part of the maps.

The quadratic structure in the lower right part of the maps (figure 1) is the position of the marker (lead with aluminium oxide in this case). Here the results from the algorithm are wrong.

A detailed manuscript about this work is in preparation [3].

The cooperation of Dr. M. Koçak (GKSS, Geesthacht) for fabricating welds is gratefully acknowledged.

References